TITLE OF THE INVENTION

Radio-frequency phase shift assembly

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application is the US national phase of international application PCT/EP00/07236 filed 27 July 2000, which designated the US.

[0002] This application is related to applicants' co-pending application serial number 10/240,317 filed October 1, 2002.

FIELD

[0003] The invention relates to a radio-frequency phase shift assembly.

BACKGROUND AND SUMMARY

[0004] Phase shifters are used, for example, for trimming the delay time of microwave signals in passive or active networks. As a known principle, the delay time of a line is used to trim the phase angle of a signal and, in consequence, a variable phase angle means that the lines have different electrically effective lengths.

[0005] For applications in antennas with an electrically adjustable notch in the polar diagram, the signals have different delay times to the individual radiating elements, for example dipoles. The difference in the delay times between two adjacent radiating elements is approximately the same for a specific notch angle in an array of radiating elements arranged

vertically one above the other. This delay time difference is also increased for larger notch angles. If the phase angles of the individual radiating elements are varied by means of phase shift assemblies, then this is an antenna with an adjustable electrical notch in the polar diagram.

[0006] According to WO 96/37922, a phase shift is known which has electrically moveable plates in order to produce a phase difference between different outputs, but at least between two outputs. This has the disadvantage that the movement of the dielectric plates also changes the impedance of the respectively affected lines, and the way in which the power of the signals is shared depends on the setting of the phase shifter.

[0007] The prior publication WO 96/37009 proposes a symmetrical line branching system in order to emit the same power at both ends of this line. This can be done provided that both ends are terminated by the characteristic impedance of this line. Comparable solutions of these technical principles have already been used for a long time for mobile radio antennas. However, these solutions have the disadvantage that only two radiating elements can be supplied, and they also still receive the same power. A further disadvantage is the moving electrically conductive connection between the input and the respective lines. Electrically high-quality contacts may exhibit undesirable nonlinearities.

[0008] In principle, it is also known for a number of phase shifters to be integrated in one antenna. Such phase shifters can supply the individual

radiating elements in the entire antenna arrangement. Individual radiating elements have different phase differences, and the phase shift assembly settings differ for the individual radiating elements. This necessitates complex mechanical step-up transmission systems such as illustrated, in principle, in Figure 1, which shows a corresponding design according to the prior art.

[0009] To this end, and in order to illustrate the prior art, Figure 1 shows, schematically, an antenna array 1 having, for example, five dipole elements 1a, 1b, 1c, 1d, 1e which are fed via a feed input 5.

[0010] The feed input 5 is followed by a distribution network 7 which, in the illustrated example, supplies two RF phase shift assemblies 9', 9") with each of the two phase shift assemblies supplying two dipoles.

[0011] A feed line 13 passes from the distribution network 7 to a central dipole radiating element 1c, which is driven without any phase shift.

[0012] The other dipoles are supplied with different phases, depending on the setting of the phase shift assembly 9, with, for example:

- the dipole 1a supplied with a phase $+2\Phi$,
- the dipole radiating element 1b supplied with a phase $+1\phi$,
- the central dipole radiating element 1c supplied with the phase $\phi = 0$,
- the fourth dipole radiating element 1d supplied with the phase -1ϕ, and

- the last dipole radiating element 1e supplied with the phase -2ϕ.

[0013] In consequence, the phase shift assembly 9' therefore ensures a split of +2ϕ and -2ϕ, and the second phase shift assembly 9'' ensures a phase shift of +ϕ and -ϕ, for the respectively associated dipole radiating elements 1a, 1e and 1b, 1d, respectively. A correspondingly different setting for the phase shift assemblies 9', 9" can then be ensured by a mechanical actuating drive 17. In this example, a comparatively complex mechanical step-up transmission 17 is used to produce the different phase differences required for the respective individual radiating elements.

[0014] A phase shift assembly of this generic type is known from PATENT ABSTRACTS OF JAPAN Vol. 1998 No. 1, January 30, 1998 (1998-01-30) & JP 09 246846 A (NTT IDO TSUSHINMO KK), September 19, 1997 (1997-09-19). This prior publication covers two stripline segments which are in the form of circle segments and are arranged offset with respect to one another in the circumferential direction and at a different distance from a central center point. A tapping element can be moved about this center point, engaging with the respective stripline segment. The tapping element in this case comprises two radial elements. The two radial elements are offset with respect to one another with an angular separation in plan view, and are connected to one another at the center point, which lies on their pivoting axis.

[0015] Exemplary illustrative non-limiting implementations of the

technology herein provide an improved phase shift assembly which has a simpler design and, particularly in the case of an antenna array using at least four radiating elements, allows an improvement to the control and setting of the phases of the individual radiating elements. In this case, power sharing, in particular in pairs, between at least four radiating elements is preferably intended to be possible at the same time.

[0016] Exemplary illustrative non-limiting implementations of the technology herein provide a phase shift assembly which is compact and, has a higher integration density. Furthermore, additional connection lines, solder points and transformation means for providing the power sharing are minimized. There is also no need for the step-up transmission system to produce and to set the different phase angles for the radiating elements.

[0017] Exemplary illustrative non-limiting implementations of the technology herein provide at least two stripline segments in the form of circle segments. They interact with a tapping element. The tapping element is connected to a feed point, and forms a moveable tap or coupling point in the overlapping area with the respective circular stripline segment. A common connection line, which extends as far as the outermost circle segment, leads from the common feed point to the individual circle segments.

[0018] As mentioned, the stripline segments may be in the form of circle segments. The stripline sections may, in general terms, also be

provided arranged concentrically with respect to one another. Such arrangement may also include stripline sections which run in a straight line and are arranged parallel to one another (namely for the situation where the radius of the stripline sections which are in the form of circle segments becomes infinite).

[0019] One exemplary simple refinement comprises providing a tapping element which passes over a number of stripline segments in the form of circle segments, like a radially running pointer. Such arrangement hence forms a number of associated tapping points which are located one behind the other in individual stripline segments.

[0020] A type of bridge structure is also possible. Connection lines which run in the same direction are arranged one above the other when seen in a horizontal side view. They can be moved about a common pivoting axis, and are rigidly connected to form a common tapping element, which can be handled.

[0021] The feed to the common rotation point is preferably capacitive. The tapping point between the tapping element and the respective circular stripline segment is also capacitive.

[0022] Exemplary illustrative non-limiting implementations of the technology herein also allow transmitting power to be shared, for example, in such a manner that the power decreases or increases from the inner to the outer circular stripline segment or, if required, even allows the power to all

the stripline segments to remain more or less constant.

[0023] Furthermore, it has been found to be advantageous for the radio-frequency phase shift assembly to be formed on a metallic base plate, which is preferably formed by the reflector of the antenna. In addition, it has been found to be advantageous for the phase shift assembly to be shielded by a metallic cover.

[0024] The distances between the circle segments may differ. The diameter of the stripline segments preferably increases by a constant factor from the inside to the outside. The distances between the circle segments may in this case preferably transmit 0.1 to about 1.0 times the transmitter RF wavelength.

[0025] One simple exemplary implementation of the phase shift assembly can also allow the circle segments and connection lines to be formed together with a cover as triplate lines.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] These and other exemplary illustrative non-limiting features and advantages will be better and more completely understood by referring to the following detailed description in conjunction with the drawings, of which:

[0027] Figure 1 shows a schematic illustration of an exemplary prior art radio-frequency phase shift assembly for feeding five dipoles;

[0028] Figure 2 shows a schematic plan view of an exemplary illustrative non-limiting implementation of a phase shift assembly for driving four radiating elements;

[0029] Figure 3 shows a schematic section along the tapping element in Figure 2, in order to explain the exemplary non-limiting capacitive coupling of the phase shift segment and of the center tap;

[0030] Figure 4 shows a modified exemplary non-limiting implementation of a phase shift assembly having three circle segments;

[0031] Figure 5 shows a modified exemplary implementation using two stripline sections which are not in the form of circle segments (which run in straight lines); and

[0032] Figures 6a and 6b show a polar diagram of an antenna array with an adjustable electrical notch at 4°, and 10°, respectively.

DETAILED DESCRIPTION OF EXAMPLE NON-LIMITING IMPLEMENTATIONS

[0033] A first exemplary implementation of a radio-frequency phase shift assembly has stripline sections 21 offset with respect to one another as shown in Figure 2. Stripline segments 21 are provided in the form of circle segments in the illustrated exemplary embodiment. An inner stripline segment 21a and an outer stripline segment 21b are arranged concentrically around a common center point in a plan view and through which a vertical pivoting axis 23 runs at right angles to the plane of the drawing.

[0034] A tapping element 25, which is designed such that it runs essentially radially in the plan view shown in Figure 2, runs from the pivoting axis 23. In each case, tapping element 25 forms a coupled tapping section or tapping point 27 in the respective area in which it overlaps an associated stripline segment 21. Two tapping points 27a, 27b are provided, in this example which are offset in the longitudinal direction of the tapping element 25.

[0035] The feed line 13 passes from the feed input 5 to a center tap 29. In that region, a pivoting axis 23 for the tapping element 25 is located.

[0036] The tapping element 25 includes a first connection line 31a. Connection line 31a extends from the coupling section 33 in the overlapping area of the center tap 29 to the tapping point 27a on the inner stripline segment 21a. The region which projects as an extension beyond this tapping point 27a forms the next connection section or connection line 31b.

Connection line 31b leads to the tapping point 27b which is formed in the region in which it overlaps the outer stripline segment 21b. The distance between the stripline sections 21a-21d may be for example 0.1 to 1.0 times the transmitted RF wavelength.

[0037] The entire RF phase shift assembly is designed with the four dipoles 1a, 1b, 1c, 1d which are shown in the exemplary embodiment in Figure 2 jointly on a metallic base plate 35, which also provides the reflector 35 for the dipoles 1a, 1b, 1c, 1d. Stripline segment 21a ends 39a, 39a' connect to antenna elements 1c, 1b through connections 41c, 41b, respectively and stripline segment 21b ends 39b, 39b' connect to antenna elements 1d, 1a through connections 41a, 41b respectively.

[0038] In the horizontal cross-sectional illustration shown in Figure 3, it can be seen that the coupling is capacitive not only at the center tap 29 but also at the tapping points 27. In this example case, low-loss dielectrics 37 provide the capacitive coupling and, at the same time, provide the mechanical fixing both for the center tap 29 and for the tapping points 27 which are radially offset with respect to it.

[0039] The base section of the center tap 29 is provided, offset with respect to the reflector plate 35, above a dielectric conical section 37a which has a greater axial height. The coupling layer 33, through which, like the center tap 29, the pivoting axis 23 likewise passes, is located above this, separated by a relatively thin dielectric conical layer 37b.

[0040] The cross-sectional illustration in Figure 3 also shows that the stripline segments 21, which are in the form of circle segments, are likewise located at the same distance as the center tap 29 from the reflector plate 37, and are coupled to the tapping element 25 via the dielectric 37 that is formed there. The tapping element 25 is in this case a uniformly rigid lever, which can be moved about the pivoting axis 23. See description of Figure 2 above for similarly labeled elements.

[0041] Rotation of the tapping element 25 about the pivoting axis 23 now allows the phase to be set, with the appropriate phase offset from $+2\Phi$ to -2Φ, jointly for all the dipole radiating elements 1a, 1b, 1c, 1d.

[0042] Suitable selection of the characteristic impedances and suitable regions of the connections 31a and 31b between the corresponding tapping points 29 as well as 27a and 27b, respectively, now allows the power to be shared at the same time between the dipole radiating elements 1a and 1d, on the one hand, and the further pair of dipole radiating elements 1b and 1c. The dipole antennas 1a to 1d are connected via antenna lines 41 to each end 39a and 39b, respectively, of the stripline segments 21a, 21b, which are in the form of circle segments.

[0043] A modified exemplary implementation with a total of six dipole radiating elements 1a, 1b, 1c, 1d, 1e, 1f is shown in Figure 4, allowing phase shifts from $+3\phi$ to -3ϕ to be achieved in this case (similarly labeled elements as compared to Figure 2 have similar functions). Furthermore, if

required, it is possible to achieve power sharing, for example from outside to inside, which allows power steps of 0.5 : 0.7 : 1.

[0044] In this exemplary embodiment, as in the previous exemplary embodiment, a central dipole radiating element or a central dipole radiating element group, as is shown in Figure 1, may also be provided, which has a phase shift angle of 0° and is directly connected to the feed line input.

[0045] Figure 5 shows two straight stripline sections 21a and 21b, which are offset with respect to one another and, in the illustrated exemplary implementation, are offset with respect to one another through 180° with respect to the pivoting axis 23 (similarly labeled elements as compared to Figure 2 have similar functions). A conversion would be feasible to the extent that the stripline sections 21a and 21b, which are shown in Figure 5, are arranged such that they run parallel to one another and run in straight lines, are arranged on the same side of the center tap 29 and, at the same time, are covered by a single tapping element 25 in the form of a pointer.

[0046] Figures 6a and 6b show the effect of a correspondingly designed antenna on the vertical polar diagram. A relatively small phase difference between the five dipoles which are shown schematically there results in a relatively small vertical depression angle, and relatively large phase difference, set via the radio-frequency phase shifter group which has been explained, results in a relatively large vertical depression angle.

[0047] While the technology herein has been described in connection

with exemplary illustrative non-limiting implementations, the invention is not to be limited by the disclosure. The invention is intended to be defined by the claims and to cover all corresponding and equivalent arrangements whether or not specifically disclosed herein.